MODIS Semi-annual Report
MOD06 Optical and Microphysical Retrievals
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and

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Abstract

Major efforts over the past six months included: (1) delivery of collection 004 algorithms, (2) participation in the CRYSTAL-FACE field experiment in July 2002, (3) continued analysis of data obtained during the SAFARI 2000 dry season campaign in southern Africa, and (4) continued analysis of MAS and CAR data from the arctic FIRE-ACE experiment.

Personnel changes

Jason Li, who had responsibility for ancillary portions of the MODIS code, MODIS atmospheric corrections, and CAR analysis, left the group in February 2002. Eric Moody, who had responsibility for incorporating MODIS land surface albedo and ecosystem maps into the operational cloud code, as well as visualization tools, left for a private company in August but then returned in November (on an expected short-term basis) to complete his work with the land products. Jérôme Riédi finished his postdoctoral position through GEST, and returned to the University of Lille in December. He worked on MODIS and MAS thermodynamic phase retrievals along with other components of the MOD06/MYD06 cloud optical properties retrieval code. He also participated in the CRYSTAL-FACE campaign as P.I. of the AirPOLDER instrument.

Several new hires were made over the last year. Gala Wind (May 2002) is working on a variety of tasks including MODIS code development and analysis of MAS/MODIS field data (SAFARI 2000, CRYSTAL-FACE). Jay Dinsick (April 2002) is managing visualization tools and web scripting. Brad Wind (December 2002) is currently working on a new joint atmosphere Level-2 data product.

I. Task Objectives

With the use of related airborne instrumentation, such as the MODIS Airborne Simulator (MAS) and Cloud Absorption Radiometer (CAR), our primary objective is to extend and expand algorithms for retrieving the optical thickness, effective radius, and water path of liquid and ice clouds using radiation measurements from the Moderate Resolution Imaging Spectroradiometer (MODIS). The secondary objective is to obtain an enhanced knowledge of surface angular and

spectral properties that can be inferred from airborne directional radiance measurements.

II. Work Accomplished

A. MODIS Code and Related Software Development

1. MOD06 Level-2 cloud retrieval code

Many updates were made to the Level-2 code as part of the collection 004 delivery. These changes are reviewed below. A history file documenting these changes and indicating retrieval impact is being developed on the atmosphere web site for MOD06/MYD06 optical, microphysical products as well as other atmosphere products (see products, availability calendar). An overview paper on the 004 cloud products was accepted for the *TGRS* Aqua special issue; a preprint is available from the web site.

a. Collection 004 Level-2 forward code – libraries (G. Wind)

A number of improvements were made to the forward code that produces the cloud radiative transfer libraries. The library output was converted from binary and ASCII (16 different files) to HDF (single file). HDF was chosen because of the ease of providing various metadata alongside the scientific data sets. The HDF improves readability and maintainability of the code as well as decreasing complexity of other software that utilized the libraries. A considerable amount of work was performed to locate and examine the original code documents to determine the identity of many, heretofore undocumented, parameters (with the assistance of Tom Arnold). Comprehensive metadata was added to aid in referencing the output, such as explanation of the parameters' meaning, physical units, if applicable, citations of sources where the parameters were originally defined, descriptions of data set dimensions, which indicated the physical quantities that a particular set depended on, etc.

The legacy forward code was converted to run under Fortran 77 in the seventies. However large portions of the code had not been updated and carried on the nomenclature of Fortran 66, which had the further restriction on length of variable names (5 characters). The code was rewritten in Fortran 90, which provided dynamic memory, removed obsolete and/or dangerous constructs and allowed longer and thus more descriptive names for the parameters. The total running time decreased from >3 hours to <20 minutes. Old instabilities in the asymptotic computations of the escape function were remedied.

Once the libraries of the Forward Code were converted to HDF, new readers were written for use in MAS processing. The new reader routines allowed for something that was not possible before, namely the ability to bring in only the parts of the libraries that fell within the range of the sensor data to be processed, as HDF offers random access to the file structure. This ability of random access

led to the possibility of significant memory usage improvement for the data processing codes that use the libraries for computations.

b. Collection 004 retrieval code - fixes and enhancements

Numerous improvements and updates were part of the collection 004 deliveries. These include:

- Improved ice crystal reflectance libraries including monotonic forcing of 3.7 µm single scattering albedo with particle size. Water and ice libraries now in HDF.

- Improved thermodynamic phase algorithm. Previous versions used results from individual cloud mask tests. The current algorithm also includes bi-spectral IR (8.5 & 11 µm) and SWIR ratio (1.6 µm / 0.67 µm and 2.1 µm / 0.67 µm) tests as well as cloud-top temperature sanity tests (*J. Riédi*). The result is that very few pixels are now flagged as "uncertain." A global example from the MODIS atmosphere high-resolution Level-3 product that demonstrates this improvement is shown in Figs. 1 and 2.

- An atmospheric emission correction was developed from the MODTRAN simulations, and incorporated into the MODIS 3.7 µm retrieval algorithm (*G. Wind*)

- Improved IGBP ecosystem map (MOD12) and albedo assignments (MOD43).

- New retrieval quality assurance assignments for optical thickness and cloud effective particle radius were developed and implemented (*G. Wind*, S. *Platnick*). This initial ad hoc approach is considered a stopgap measure until

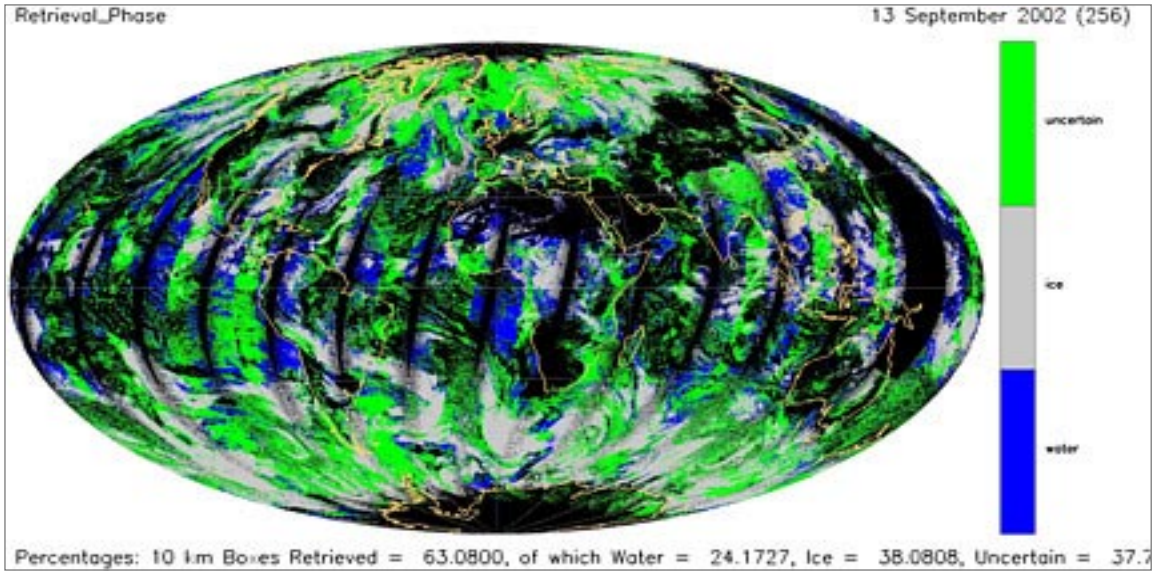

Figure 1. MODIS high resolution Level-3 daily thermodynamic phase retrieval for 13 September 2002 (collection 003 data).

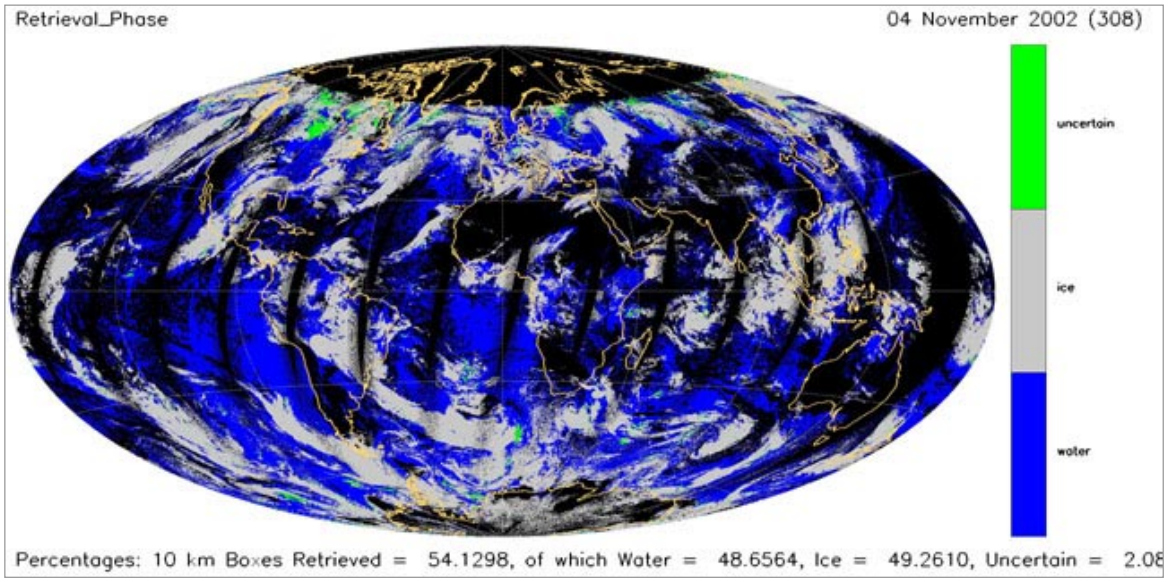

Figure 2. MODIS high resolution Level-3 daily thermodynamic phase retrieval for 4 November 2002 (collection 004 data). Note the absence of 'uncertain' phase (2% of grid boxes) compared to Fig. 1 (37%).

sensitivity libraries (*S. Platnick*) can be incorporated into the algorithm.

- Various bug fixes and code efficiency improvements.

c. Alternative retrieval code available for testing and development

G. Wind adapted the Platnick MAS cloud retrieval code (water clouds) to perform cloud retrievals using MODIS data. This provides a code against which the results of the operational MODIS code can be compared. Ice libraries for the Platnick code are in the works. Preliminary water cloud retrievals are similar to those of the operational MODIS code. However, the Platnick MODIS code gives smaller radii and higher optical thicknesses than the operational code (for SAFARI 2000 stratocumulus granules). The results of the Platnick MODIS code were also compared with the relevant parts of the Platnick MAS SAFARI retrievals.

d. Ancillary surface albedo maps (E. Moody)

Philosophy:

- Creation of value-added albedo data sets based on MODIS land products (MOD12, MOD43) for use by both the MODIS science team and the greater community. Specifics include:

  - Mosaicing of official albedo data sets stored in Integerized Sinusoidal Projection onto rectangular coordinate maps, at one-minute resolution, and application of quality assurance (see example of 1.6 μm white sky albedo in Fig. 3).

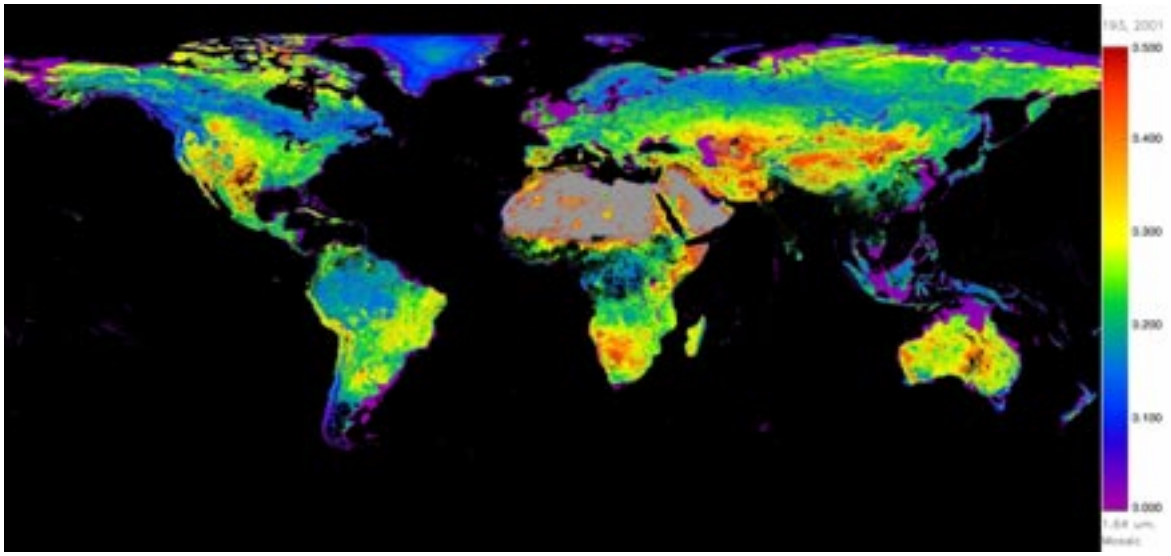

Figure 3. A mosaicing of the MOD43 white sky albedo for July 2001 from the native integerized sinusoidal projection onto a rectangular grid for the 1.6 µm MODIS band.

- Filling in missing points in official data with statistics based upon ecosystem classification (example 1.6 µm white sky albedo in Fig. 4).

- Generation of albedo statistics based upon ecosystem classifications over half-degree boxes to accurately represent the latitudinal and longitudinal variations in albedo with ecosystem.

- Creation of seasonal albedo model by temporally fitting the albedo / ecosystem statistics.

Albedo processing codes written:

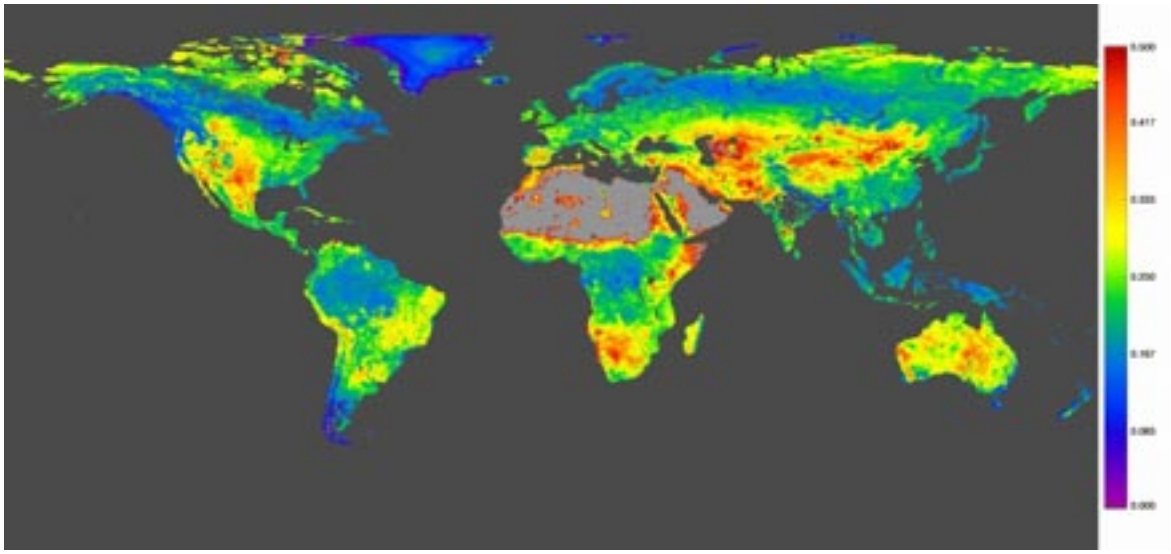

Figure 4. The MODIS 1.6 µm white sky albedo for July 2001 generated from 0.5° ecosystem-albedo statistics. Note that missing data in Fig. 1 is filled in when using ecosystem as a proxy for albedo. An albedo of 0.05 is assigned to ocean regions.

- Code that mosaics official albedo data sets stored in Integerized Sinusoidal Projection onto rectangular coordinate maps at one-minute resolution. Maps, Quality Assurance (QA) and metadata are stored in the resulting HDF output files.

- Code that applies QA to the rectangular coordinate maps and imposes a simulated polar darkness, with results, QA, and metadata stored in HDF files.

- Code that mosaics official ecosystem classification data sets stored in Integerized Sinusoidal Projection onto rectangular coordinate maps at one-minute resolution. Maps, QA and metadata are stored in HDF output files.

- Code that computes albedo mean, standard deviation, number of points, and sum (used to combine statistics) for each ecosystem classification within a N x N degree (currently set to 0.5°) box.

Albedo visualization codes written:

- Codes that produce global plots of albedo and ecosystem classification in rectangular coordinate maps.

- Codes that produce images of official albedo and ecosystem classification data sets stored in Integerized Sinusoidal projection.

- Codes that produce global images of albedo / ecosystem statistics and reproduction of albedo maps solely using the albedo / ecosystem statistics.

e. Miscellaneous Level-2 analysis

- A cross-comparison of Wisconsin cloud top properties product and MISR Stereo Cloud Top product is being conducted (*G. Wind*). In the few results thus far obtained, the Wisconsin product shows a bias of as much as 300 hPa for low clouds. Further investigation is necessary and will be conducted soon on CRYSTAL-FACE data.

- The entire group continued to examine MODIS Level-2 and Level-3 retrieval visualizations for artifacts.

f. Atmosphere's combined Level-2 product

Brad Wind has put together a draft design of a proposed reduced-size joint atmosphere Level-2 product (cf. Table 1). The combined file will include data from the cloud mask, aerosol, atmospheric profiles, and cloud products. To date, each daytime granule will be roughly 3.2 MB in size while nighttime granules will be 1.3 MB (vs. 65 MB for MOD06 and 48 MB for cloud mask) allowing an entire day of data to be placed on a CD.

TABLE 1. Science Data Sets of the new MODIS Level-2 Joint Atmosphere Product

	SDS Size (kB)	
Science Data Set	Daytime	Nighttime
Global Attributes	75	75
Cloud mask (1st byte)	109	109
Cloud optical thickness	219	
Cloud effective radius	219	
Cloud top pressure	219	219
Cloud phase daytime	109	
Cirrus reflectance	219	
Precipitable water (near infrared clear sky)	219	
Precipitable water (thermal infrared)	219	219
Latitude (5 km)	219	219
Longitude (5 km)	219	219
Solar zenith angle (5 km)	219	
Zenith angle (5 km)	219	219
Relative azimuth angle (5 km)	219	
Aerosol optical thickness	54	
Aerosol optical thickness ratio (fine mode to total)	54	
Aerosol effective radius (ocean)	109	
Latitude (10 km)	54	
Longitude (10 km)	54	
Solar zenith angle (10 km)	54	
Zenith angle (10 km)	54	
Relative azimuth angle (10 km)	54	
Total size (kB)	**3189**	**1279**

2. MOD08 Level-3 joint atmosphere code (Paul Hubanks)

Modifications were made to the Fortran 77 and/or Fortran 90 software, CDL file specifications, and corresponding HDF structure files for the MODIS Atmosphere Joint Level-3 Products: MOD08 (Terra) and MYD08 (Aqua) for low-resolution Tile, Daily, Eight-Day, and Monthly and high-resolution Tile and Daily. Specific changes include:

a. Tile & Daily (Low Resolution 1°)

Histogram and Confidence Histograms. Code modifications related to the handling of Level-2 fill values in the computation of histograms and confidence histograms were implemented as follows: (i) Histogram bin counts for grid cells

listing only Level-2 fill values had previously all been set to 0. In the new code, all bin counts for such grid cells are set to the Level-3 fill value. (ii) Confidence histograms had tallied Level-2 fill values along with valid observations into the total counts for a grid cell. In the new algorithm, fill values are screened and not counted. In addition, earlier versions of the confidence histogram code did not separate Level-2 pixels into aggregation categories as intended. This is rectified in the current delivery. Finally, the software was modified by adding a logic branch to handle a real histogram when no QA data are available. This was needed for several MOD04 parameters, where previously these 'no QA' Histograms were unpopulated.

Logarithmic Statistics. A bug in the code relating to the computation of the Logarithmic statistics was corrected (applicable to Cloud_Optical_Thickness only). Previously all log statistics were computed using the natural log. This has now been corrected to use the common log as documented. Also corrected the CDL file spec and HDF template file by changing the 'longname' local attribute of all Log SDSs from 'log of statistic' to 'statistic of log' (e.g., "Log of Mean" corrected to "Mean of Common Logarithm"). Finally, the scale factor was optimized, the necessary offset added, and the valid range corrected for all log statistics.

QA Weighted Statistics. Updated the CDL file spec and HDF template file by removing the QA attributes and QA SDSs from all cloud top parameters (derived from MOD06_CT). This was done to rectify an error in the MOD06_L2 product where all clear pixels were assigned a QA value of 0 instead of the intended value of 3. Moreover, if all QA values were in fact set to 3 as intended, QA weighted statistics in Level-3 would render the same results as unweighted statistics, providing no added value.

Pixel Counts. The Pixel_Counts SDS for Cirrus Reflectance was dropped because it was found unnecessary.

QA Weighting Function. A new QA weighting function was introduced. The QA definition was slightly altered. Now QA = 0 can mean:

- Fill (Missing) Level-2 pixel or
- Level-2 pixel (most likely in the valid range of data) in which we have no confidence

In the first case, the Level-2 pixel (which is a fill value) is not included in any statistical computation. In the second case, the Level-2 pixel WILL BE included in the unweighted statistics but not in the QA-weighted statistics (noted by a "QA" in the SDS name at Level-3, e.g., "QA_Mean"). Note that the only Level-3 statistics that are QA-weighted are the simple statistics and log statistics.

b. 8-Day and Monthly (Low Resolution 1°)

CDL File Specification and HDF Structure File Changes. Modified the CDL file spec and HDF template file as follows:

- Optimized the scale factor, added the necessary offset, and corrected the valid range for all log statistics.
- Changed the Statistic_Type local attribute for all log statistics from "Logarithmic" to "Simple" and "Simple_Std". This allows the software to compute and write out common logarithm statistics without necessitating any complex software changes. (Previously all log statistics were unpopulated.) Note that the only parameter that is specified to compute and store log statistics is Cloud_Optical_Thickness.
- Corrected the "Derived From Level-3 Daily Data Set" local attribute for several of the Cloud Optical Thickness SDSs. A number of these were specified incorrectly and this prevented population of the associated arrays.
- Removed QA attributes & QA-related SDSs from all Cloud Top Properties parameters (those derived from MOD06_CT). They are replaced by simple unweighted statistics.
- The QA attributes & all QA-related SDSs for the Cirrus_Reflectance parameter were removed. They were found to be redundant with the simple statistics.

c. Tiling & Daily (High Resolution 0.1°)

Mean and QA-weighted Means. Modified the software such that ONLY the Mean and QA_Mean (QA weighted mean) SDSs are populated. This was necessary in order to free space in the HDF file so that the number of parameters stored in the file could be markedly increased.

Derivation of Mean Statistic. Modified the software so that the derivation of the Mean statistic matches the one recently redefined in the low resolution version of the code, namely that non-fill Level-2 input pixels with QA = 0 are now INCLUDED in the Mean computation (however they are still excluded from the QA_Mean, as before).

New Parameters. In order to make the high-resolution HDF product file more useful, the following parameters were added:

- Sensor_Zenith
- Sensor_Azimuth
- Corrected_Optical_Depth_Land
- Reflected_Flux_Land
- Mean_Reflectance_Land_All
- Path_Radiance_Land
- Critical_Reflectance_Land
- Effective_Optical_Depth_Average_Ocean
- Effective_Radius_Ocean

- Transmitted_Flux_Average_Ocean
- Cloud_Top_Temperature_Day
- Cloud_Top_Temperature_Night
- Cloud_Top_Pressure_Day
- Cloud_Top_Pressure_Night
- Cloud_Fraction_Infrared
- Cloud_Fraction_Infrared_Day
- Cloud_Fraction_Infrared_Night
- Effective_Radius_Difference_Combined
- Effective_Radius_Difference_Water
- Effective_Radius_Difference_Ice
- Effective_Radius_Difference_Undetermined

The new high-resolution daily HDF product file is now 1.3 GB in size, about 20% larger than the previous version.

3. MODIS Atmosphere Web Site Development

Paul Hubanks continued to update and add numerous items to the MODIS Atmosphere web site. Most notably, he as added a processing and availability calendar (modis-atmos.gsfc.nasa.gov/products_calendar.html). The table includes the software revision documentation for all atmosphere PGEs.

Jay Dinsick has scripted much of the image creating for the web site, including: Perl scripts to automate: (i) Creation of the Level 3 High Resolution (Terra) and Low Resolution (Terra, Aqua) imagery. (ii) Creation of web pages for the Level-1B (Terra, Aqua), Level 3 High Resolution (Terra), and Level 3 Low Resolution (Terra, Aqua) imagery. The scripts update the web pages daily.

4. MODIS product visualizations and other software tools

Jay Dinsick developed a tool for reprocessing Terra and Aqua granules using the latest collection 004 algorithms (MOD35 and MOD06). It can be used for reprocessing a single granule, a range of granules, or a whole day of data.

5. MODIS brochures

Mark Gray created a number of optimized gray-scale images for use in the updated EOS Data Products Handbook for MODIS-Atmosphere related products.

B. MODIS-related Instrument Efforts

1. Cloud Absorption Radiometer (CAR)

a. Aerosol, BRDF inversion studies

Over the past six months, Charles Gatebe, along with Oleg Dubovik, has been involved in developing of a new inversion scheme to simultaneously retrieve aerosol optical properties and surface BRDF using CAR data. These will be ap-

plied to data previously obtained over the Brazilian Cerrado, oceanic regions (TARFOX, SCAR-A, CLAMS), desert areas (Kuwait Oil Fire Smoke Experiment), southern Africa (SAFARI 2000), including Mopane and Miombo woodlands of southern Africa and Pans of Botswana and Namibia, and Arctic tundra and sea ice (ARMCAS, FIRE-ACE, and LEADEX).

b. CLAMS

Level-1A data and quick looks have been posted to the CAR web site. Documentation of CAR measurements during CLAMS has been completed and posted to the CAR web site.

c. CAR web site

Paul Hubanks continued work and maintenance on the Cloud Absorption Radiometer (CAR) web site. No major activities to report.

2. MODIS Airborne Simulator (MAS)

Mark Gray continued development of a MAS version of the MODIS cloud retrieval code, including use of the latest routines developed for MODIS collection 004 algorithms. Tom Arnold led the effort on a MODIS-like cloud mask and thermodynamic phase algorithm implementation for MAS. Much of his time was spent on problem areas such as sun glint regions. The initial version of this MAS code is being tested on SAFARI 2000, FIRE-ACE, and CRYSTAL-FACE data sets.

The results of the Platnick MODIS code (see *II.A.1.c*) were also compared with the relevant parts of the Platnick MAS SAFARI retrievals. Along with MODIS-MAS scene comparisons, this led to the conclusion that the visible-near IR MAS port calibration was reporting higher reflectances (~+20%) compared with MODIS for cloudy scenes. However, for low reflectance scenes (i.e., land and ocean), MAS and MODIS are comparable. Complete SAFARI 2000 analysis is ongoing (*G. Wind*).

C. MODIS-related Field Campaign and Validation Efforts

1. CRYSTAL-FACE

The NASA CRYSTAL-FACE field campaign during July 2002 sought to understand the life cycle and radiative properties of anvil cirrus and involved six aircraft, 2 ground sites, and several hundred scientists. It will serve as the first MODIS validation activity for ice cloud optical and microphysical retrievals.

Steve Platnick, Michael King, Jérôme Riédi, Tom Arnold, and Eric Moody participated in the campaign (out of Key West). Participation by Platnick and King included PIs of the MAS instrument flown on the NASA ER-2, participation in

the CRYSTAL-FACE management team, and ER-2 flight scientist duties. Jérôme Riédi was funded by CNES to fly the AirPOLDER (POLDER; POLarization and Directionality of the Earth Reflectances) instrument on the Proteus aircraft, providing directional and polarimetric observations useful for inferring cloud phase, particle habit, and bidirectional reflectance patterns. Furthermore, simultaneous observations of POLDER and MAS during CRYSTAL-FACE provided a valuable dataset to help in designing new synergistic algorithms with MODIS/Aqua and PARASOL during the A-Train time frame (post-2004).

The ER-2 flew 11 science missions, comprising over 70 flight hours, usually in close coordination with other remote aircraft (Proteus) and in situ aircraft (NASA WB-57, UND Citation). A variety of convective systems and thin cirrus were observed. Many flights included underflights of Terra (3), Aqua (6), and TRMM (2). Other investigators include the members of the MISR science team, NPP test bed personnel, etc.

An example MODIS retrieval of the southern Florida regions is shown in Fig. 5 where strong convection is seen occurring over the peninsula during the Aqua overpass on 23 July 2002. An example MAS retrieval is shown in Fig. 6. Quicklook imagery developed by Tom Arnold, and IDL-based thermodynamic phase and cloud mask retrievals generated for all MAS flight tracks are available on the MAS web site.

2. SAFARI 2000

SAFARI 2000 activities marked the first validation effort for the MODIS liquid water cloud retrieval product. Steve Platnick, Tom Arnold, and Gala Wind

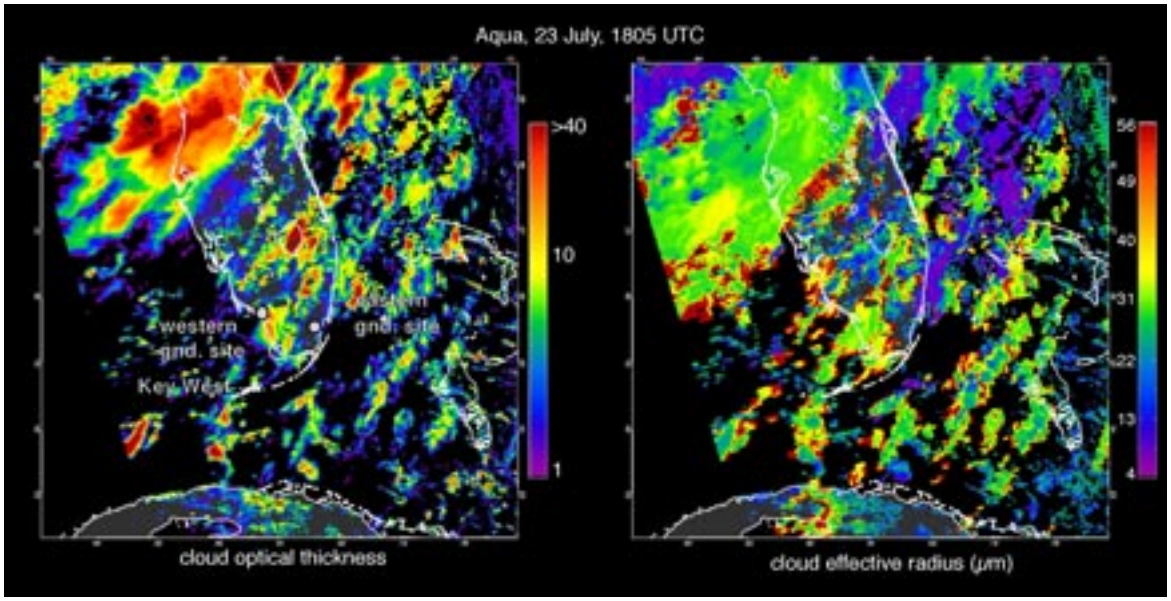

Figure 5. Example CRYSTAL-FACE Aqua imagery from 23 July 2002, showing MDY06 cloud optical thickness and effective radius retrievals. Southern Florida aircraft operating location (Key West) and the two ground sites are shown in the left panel.

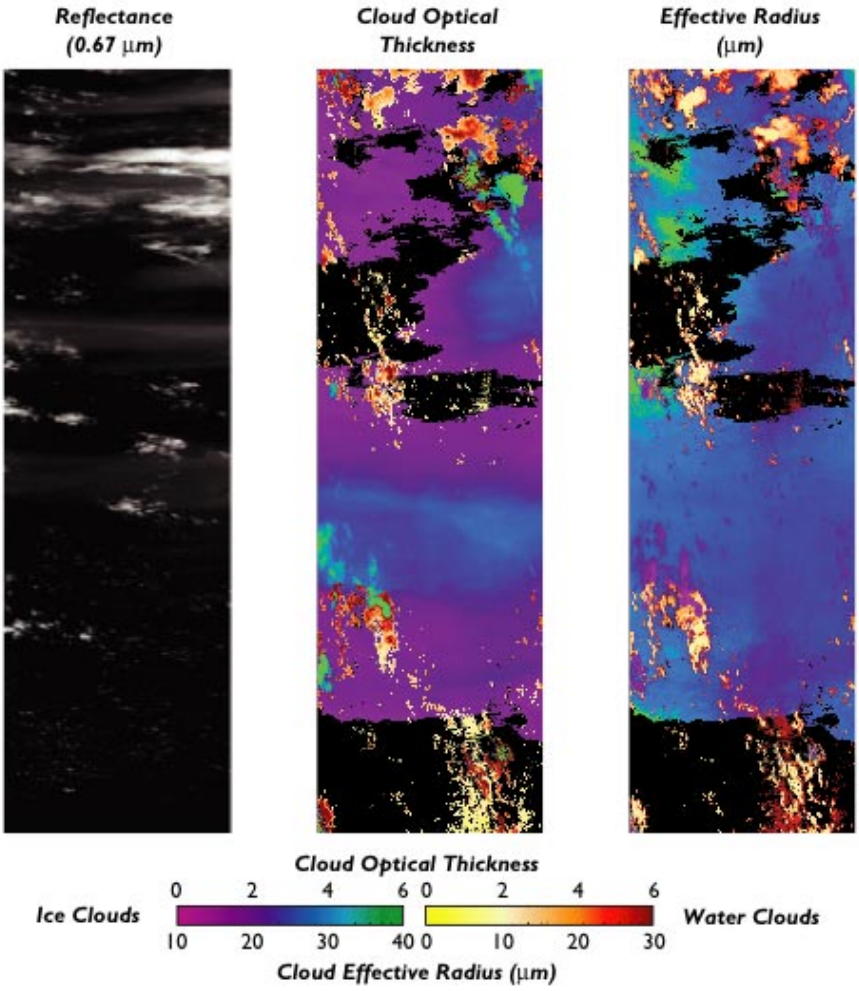

Figure 6. Example CRYSTAL-FACE MAS imagery and cloud optical properties retrievals from 26 July 2002 off the coast of Nicaragua.

worked with in situ cloud data received from the University of Washington CV-580 and UK Meteorological Research Flight C-130H during validation efforts off the coast of Namibia. A comparison of the in situ data with MODIS retrievals has been completed (using the latest algorithm updates). MAS retrievals using the Platnick retrieval code have been completed. Both MODIS and MAS size retrievals were generally found to be larger than the in situ measurements, though MAS retrievals are typically closer to the in situ; optical thickness retrievals are in general agreement. These analyses are being finalized and will be combine with Level-3 cloud statistics for the SAFARI region for publication.

All SAFARI granules were reprocessed with collection 004 MOD35 and MOD06 operational code (*Dinsick*), with sunglint logic disabled (so as to acquire more clouds in the sun glint region). These data sets are being analyzed by Paul Hubanks with the Level-3 high resolution code and will be compared with similar MODAPS results (but sunglint logic enabled).

MAS imagery for 20 August 2000 SAFARI-2000 over the Madikwe Fire (for use in

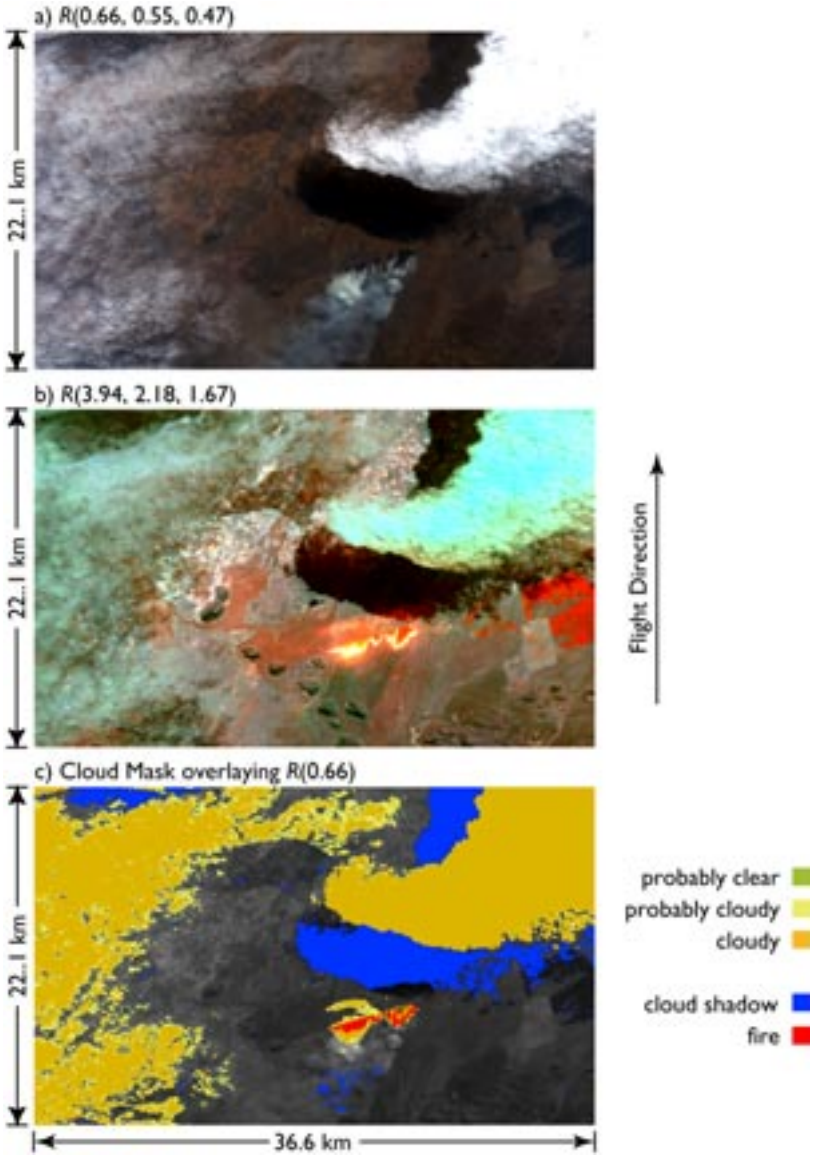

Figure 7. MAS images of a prescribed fire and nearby clouds were acquired over the Madikwe Private Game Reserve, South Africa, on 20 August 2000. Panel (a) is a true color RGB composite of bands at 0.66, 0.55, and 0.47 μm, (b) a false color composite of bands at 3.94, 2.18, and 1.67 μm, and (c) the resultant cloud, shadow, and fire mask. The thermal emission of the hot fire line clearly shows up beneath the smoke using the shortwave infrared bands.

a publication by King et al., 2003) was remapped (for geometric correction) and true and false color images over and near fire were produced (*G. T. Arnold*). As a part of the effort, code was written to also remap the corresponding MAS cloud mask data for this region and generate a remapped cloud mask image. Analysis of the cloud mask imagery shows too much of image identified as "cloud shadow," so ways were investigated to improve the cloud shadow detection algorithm. A refined algorithm was determined and implemented for the cloud mask image (cf. Fig. 7). Additional analysis will be necessary to determine if modified algorithm can be applied to other data cases.

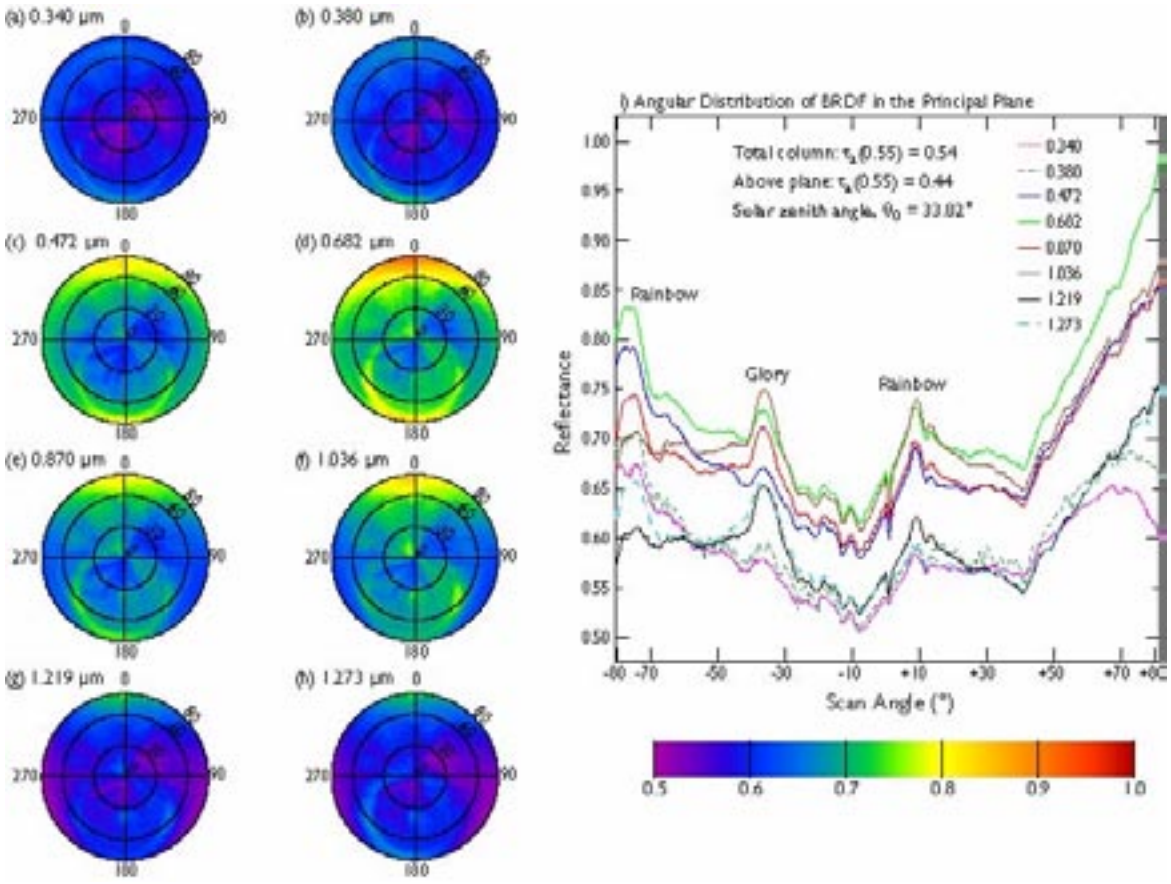

Figure 8. Spectral BRDF measurements of Namibian marine stratocumulus clouds derived from CAR measurements on 13 September 2000 during SAFARI 2000.

A paper on CAR measurements by Charles Gatebe et al. was accepted in the *JGR* SAFARI special issue. An example BRDF measurement was made over marine stratocumulus off the coast of Namibia as shown in Fig. 8. Panels (a)-(h) show the BRDF pattern for individual CAR spectral bands; panel (i) shows principal plane plots with view angles looking towards (positive scan angles) and away from the sun (negative sun angles). Single scattering features such as the rainbow and glory are clearly distinguished.

Tom Arnold worked with Charles Gatebe and Jaime Nickeson on formatting CAR SAFARI BRDF data for release to the public. All SAFARI BRDF data were processed.

3. FIRE-ACE

Further analysis has awaited completion of the MAS version of the MODIS cloud retrieval code. Final MAS retrieval processing is expected in February to March 2003. In the meantime, the draft paper has been updated to include the collection 004 MODIS-like thermodynamic phase algorithm.

4. CLAMS

Tom Arnold performed additional CAR roll correction processing for the Chesapeake Lighthouse & Aircraft Measurements for Satellites 2001 (CLAMS 2001) experiment. The correction algorithm was applied to most CAR data not previously corrected. Also CLAMS data to which the correction algorithm had previously been applied was carefully reviewed, and additional adjustments were made as appropriate.

III. MODIS Problems/Corrective Actions and Status

The main emphasis over this reporting period was improvements and fixes to the operational algorithm, and their implementation into the collection 004 processing. All of following items from this section in the last report have been fixed: (i) retrieval frequency distribution anomaly, (ii) large effective radius retrievals associated with small optical thickness retrievals in ocean water clouds, (iii) thermodynamic phase results with large number of "uncertain" phase retrievals, (iv) 3.7 µm failed particle size retrievals, and (v) conflicts between NICE snow-free land conflicting with IGBP permanent ice. The only remaining item from that list (rejection of cloudy pixels in sunglint regions) was investigated with spatial variance tests but with no clear operational means of implementation. That investigation is ongoing.

IV. Anticipated Future Actions

1. Propose to re-competition NRA.

1. MODIS atmosphere team meeting, tentatively scheduled for 17-19 March.

1. Monitor performance of the cloud retrieval code in production.

1. Update reflectance libraries as needed.

1. Continue development of ancillary surface albedo product; visit Boston University to discuss use of Boston MOD12 and MOD43 products; begin synthesis of work for journal publication.

1. Continue to compare cloud particle size retrievals using the three different SWIR / MWIR bands (at 1.6, 2.1, 3.7 µm).

1. Duplicate additions / corrections / features of the MODIS code in the MAS version of the cloud retrieval code.

1. Evaluate anomalous non-monotonic behavior of diffusion domain parameters in reflectance libraries and implement a correction.

1. Continued analysis of SAFARI 2000 dry season (August-September 2000), FIRE-ACE (May-June 1998), and CRYSTAL-FACE (July 2002) field cam-

paigns.

1. Continue work on development of a new inversion scheme to simultaneously retrieve aerosol optical properties and surface BRDF with CAR measurements.

1. Finalization of combined atmosphere Level-2 product specification and production of example files.

V. Publications

A. Published

1. Arnold, G. T., S. C. Tsay, M. D. King, J. Y. Li and P. F. Soulen, 2002: Airborne spectral measurements of surface-atmosphere anisotropy for Arctic sea ice and tundra. *Int. J. Remote Sens.*, **23**, 3763–3781.

1. King, M. D., and D. D. Herring, 2002: Research satellites (atmospheric sciences). *Encyclopedia of Atmospheric Sciences*, J. R. Holton, J. A. Pyle, and J. A. Curry, Eds., Academic Press, 2038–2046.

B. Accepted

1. King, M. D., W. P. Menzel, Y. J. Kaufman, D. Tanré, B. C. Gao, S. Platnick, S. A. Ackerman, L. A. Remer, R. Pincus, and P. A. Hubanks, 2003: Cloud and aerosol properties, precipitable water, and profiles of temperature and humidity from MODIS. *IEEE Trans. Geosci. Remote Sens.*, in press.

1. Platnick, S., M. D. King, S. A. Ackerman, W. P. Menzel, B. A. Baum, J. C. Riédi, and R. A. Frey, 2003: The MODIS cloud products: Algorithms and examples from Terra. *IEEE Trans. Geosci. Remote Sens.*, in press

1. King, M. D., S. Platnick, C. C. Moeller, H. E. Revercomb and D. A. Chu, 2003: Remote sensing of smoke, land and clouds from the NASA ER-2 during SAFARI 2000. *J. Geophys. Res.*, in press.

1. Gatebe, C. K., M. D. King, S. Platnick, G. T. Arnold, E. F. Vermote, and B. Schmid, 2003: Airborne spectral measurements of surface-atmosphere anisotropy for several surfaces and ecosystems over southern Africa. *J. Geophys. Res.*, **108**(**?**), XXXX, doi:10.1029/2002JD002397.

VI. MODIS-related Services, Presentations, and Meetings

A. Outreach

1. M. D. King organized a Terra course as part of the International Summer School on Atmospheric and Oceanic Sciences at Scuola Superiore Guglielomo Reiss Romoli in L'Aquila, Italy, 25-30 August 2002. Course lectures included

M. D. King: "Introduction to the course and principles of radiative transfer, scattering and orbits"

M. D. King: "Remote sensing of atmosphere, land and ocean properties from Terra"

S. Platnick: "MODIS cloud retrievals: Cloud mask, cloud top properties, optical and microphysical properties"

1. From 18 July-27August, C. K. Gatebe visited Kenya for outreach activities aimed at promoting satellite observations and applications at a regional level in such activities as environmental assessment, meteorological observations, disaster mitigation, coastal studies, marine observations, Earth resources surveys and management, and various other civil works.

B. Meetings

1. King and Platnick attended the *SAFARI 2000 Synthesis Workshop*, University of Virginia, Charlottesville, 7-11 October 2002.

1. King, Platnick, and Moody attended the *SPIE 3rd International Asia-Pacific Environmental Remote Sensing*, Hangzhou, China, 23-27 October 2002.

1. King attended the *Workshop on GAME-T and Hydrometeorological Studies*, in Chiang Rai, Thailand, 29-30 October 2002.

1. King and Platnick attended the *EOS Investigators Working Group Meeting*, Ellicott City, Maryland, 18-20 November 2002.

C. Presentations

1. Gatebe, C. K., M. D. King, S. Platnick, G. T. Arnold, E. F. Vermote and B. Schmid, POSTER: Airborne Multi-Spectral Measurements of Surface-Atmosphere Anisotropy for Several Surfaces and Ecosystem over Southern Africa, *SAFARI 2000 Synthesis Workshop*, University of Virginia, Charlottesville, October 7-11, 2002.

1. Gatebe, C. K., M. D. King, S. Platnick, G. T. Arnold, E. F. Vermote and B. Schmid, POSTER: Airborne Multi-Spectral Measurements of Surface-Atmosphere Anisotropy for Several Surfaces and Ecosystem over Southern, Africa, *MODIS Workshop on Land Surface Radiation Budget Variables and Snow and Ice Products*, Boston University, October 21-22, 2002.

1. King, M. D., S. Platnick, S. A. Ackerman, W. P. Menzel, M. A. Gray and E. G. Moody, 2002: Multispectral cloud retrievals from MODIS on Terra and Aqua. Presented at the *SPIE Symposium on Remote Sensing of the Atmosphere, Environment, and Space*, Hongzhou, China (invited), 23-27 October.

2. King, M. D., S. Platnick, and E. G. Moody, 2002: Remote sensing of cloud,

aerosol, and land properties from MOIDS: Applications to the East Asia region. Presented at the *GAME-T Workshop on Hydrometeorological Studies*, Chiang Rai, Thailand (invited), 29 October.

3. Moody, E. G., M. D. King, S. Platnick, and C. B. Schaaf, 2002: A white-sky surface albedo data set derived from Terra MODIS data. Presented at the *SPIE Symposium on Remote Sensing of the Atmosphere, Environment, and Space*, Hongzhou, China, 23-27 October.

4. Platnick, S., et al.: Cloud science and validation activities during SAFARI 2000, *SAFARI 2000 Synthesis Workshop*, Charlottesville, VA, 7-11 October 2002.

5. Platnick, S., M. D. King, M. Gray, G. Moody, P. V. Hobbs, S. Osborne, S. Piketh and R. Swap, 2002: Satellite and aircraft cloud remote sensing validation studies during SAFARI 2000. Presented at the *SPIE Symposium on Remote Sensing of the Atmosphere, Environment, and Space*, Hongzhou, China (invited), 23-27 October.

6. Privette, J. L., M. Mukelabai, C. K. Gatebe and C. Schaaf, Evaluation of the MODIS BRDF/Albedo Products over Zambia Using Aircraft and Tower based Measurements. *SAFARI 2000 Synthesis Workshop*, University of Virginia, Charlottesville, October 7-11, 2002.

VII. Awards

1. Michael King and Steven Platnick received the *NASA Group Achievement Award* as part of the SAFARI 2000 International Leadership Team (along with R. J. Swap (UVa), H. J. Annegarn (U. Witwatersrand), J. T. Suttles, J. L. Privette, and R. J. Scholes).

VII. Web sites

The Cloud Retrieval Group, MODIS Atmosphere, MAS, and CAR web sites can be found at:

ltpwww.gsfc.nasa.gov/crg
modis-atmos.gsfc.nasa.gov
mas.arc.nasa.gov
car.gsfc.nasa.gov